Integration of precision NASA snow products with the operations of the Colorado Basin River Forecast Center to improve decision making under drought conditions

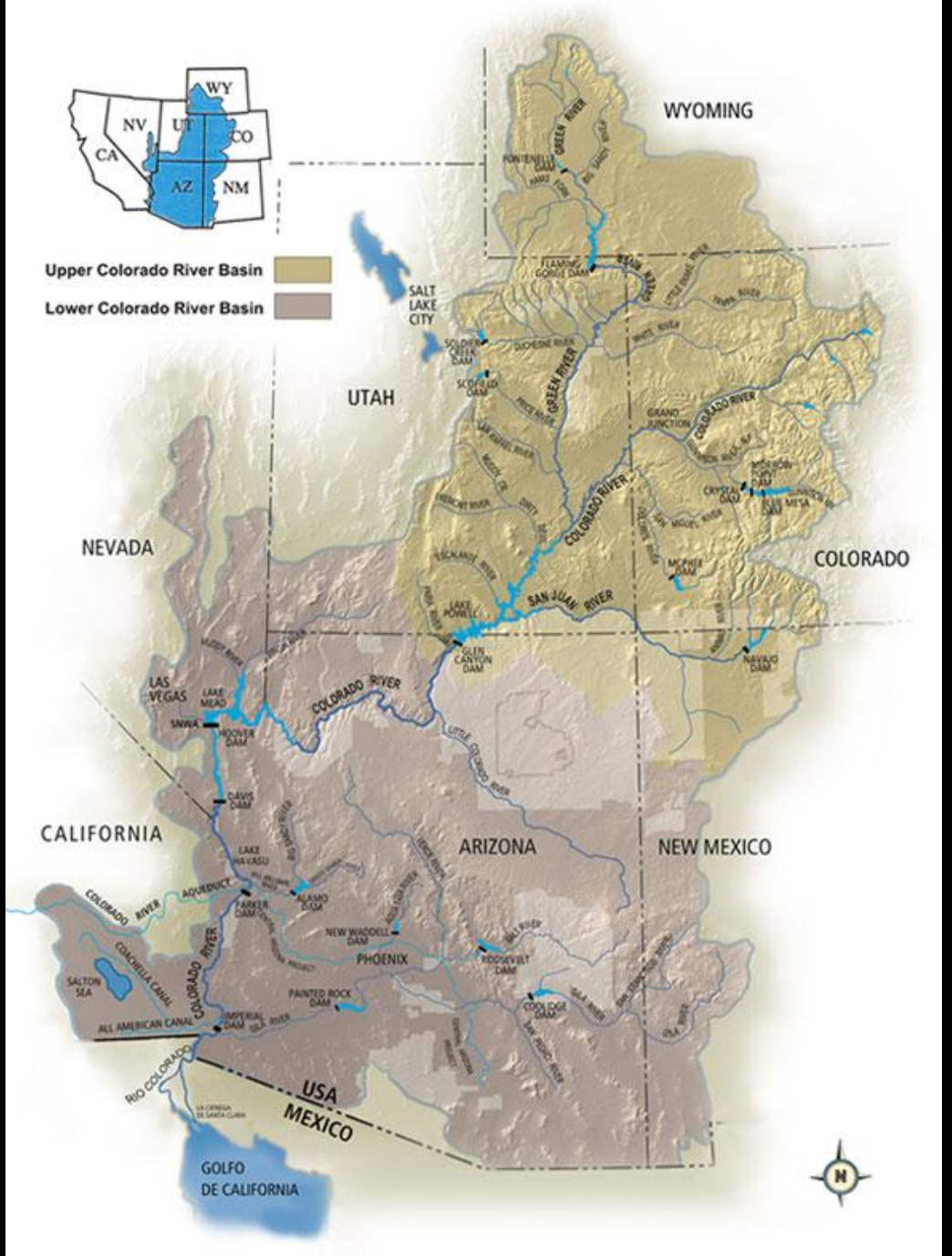
T. H. Painter, C. Mattmann | JPL/Caltech

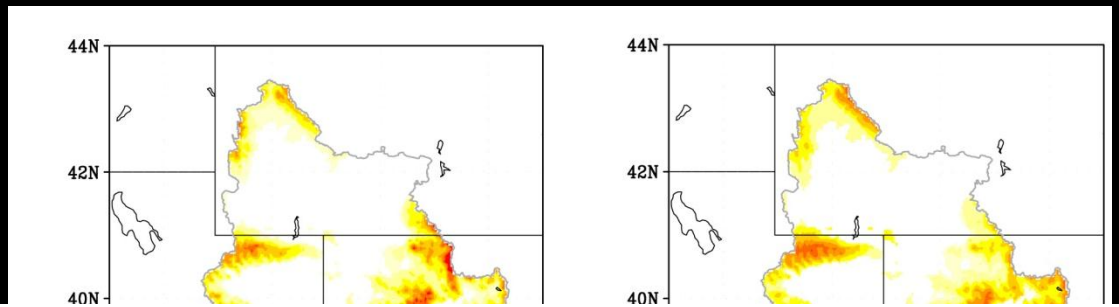
Kevin Werner, Stacie Bender, Michelle Stokes | NWS CBRFC

Statement of Problem

As drought frequency increases in the CRB, it is critical that the Colorado Basin River Forecast Center (CBRFC) and the dependent water managers have more comprehensive real-time knowledge of the snow cover and its properties for more precise runoff forecasting and stakeholder decision support.

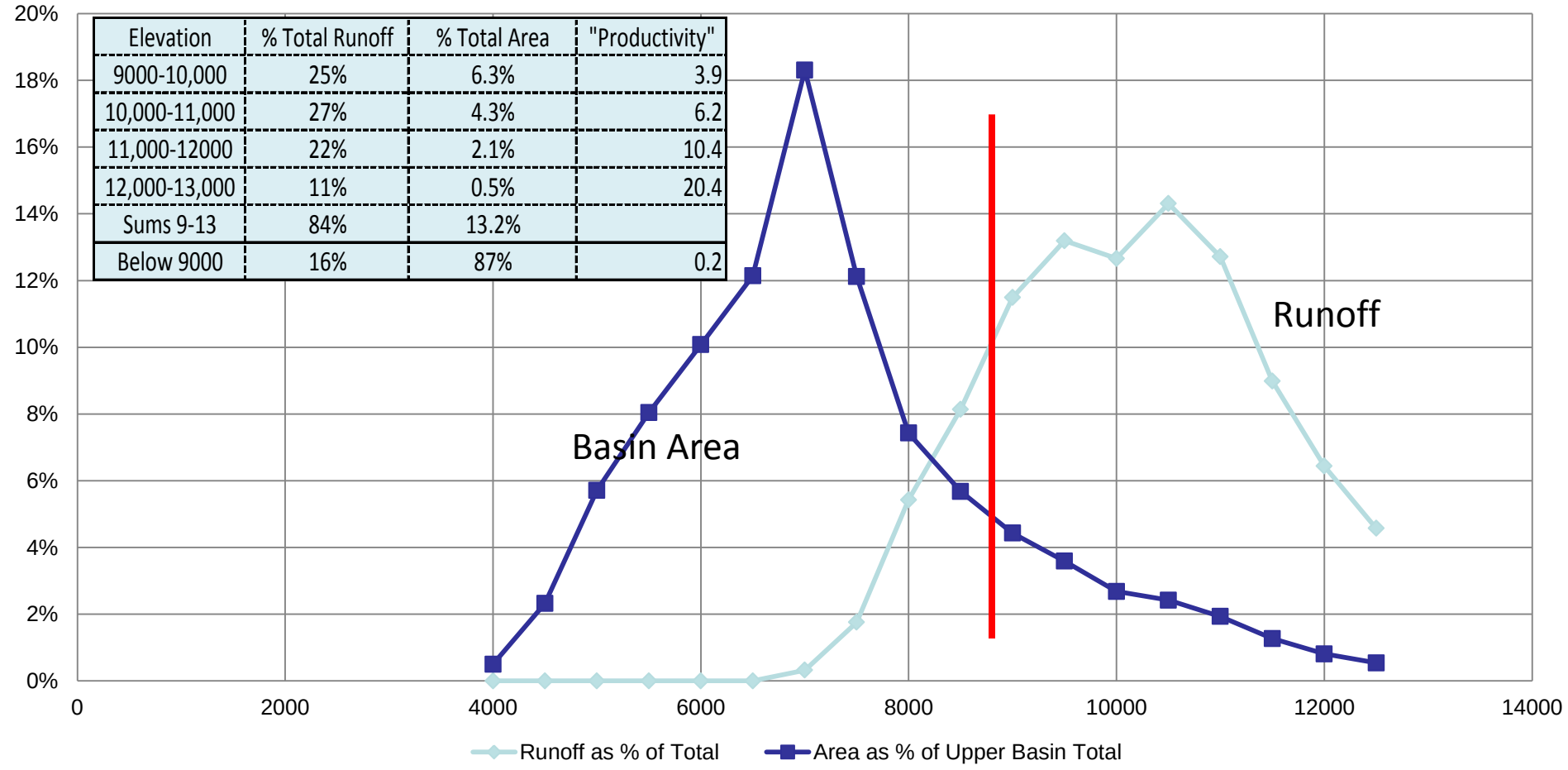
Colorado River Basin





Basin Area and Runoff By Elevation

Elevation	% Total Runoff	% Total Area	"Productivity"
9000-10,000	25%	6.3%	3.9
10,000-11,000	27%	4.3%	6.2
11,000-12000	22%	2.1%	10.4
12,000-13,000	11%	0.5%	20.4
Sums 9-13	84%	13.2%	
Below 9000	16%	87%	0.2



CBRFC operations

The NOAA/NWS Colorado Basin River Forecast Center (CBRFC) is responsible for generating daily and seasonal long lead streamflow forecasts in both the Colorado River Basin and eastern Great Basin. Forecasts are used by a variety of stakeholders to inform decision-making about water management, flood mitigation, and recreation.

Partner End-User Organizations

- **Colorado River Water Conservation District (Eric Kuhn)**
- **Bureau of Reclamation Upper Colorado Region (Dan Crabtree)**
- **Denver Water (Bob Steger)**
- **National Weather Service-Grand Junction Office (Mike Meier)**
- Broader community who will go through training – CRWUA (w Ana Prados)

Feasibility Study

Applied Sciences Strategic Goals	Feasibility Task
1. Enhance applications research: Advance the use of NASA Earth science in policy making, resource management and planning, and disaster response	Directly integrate MODIS snow products into CBRFC SNOW-17 modeling and forecasting and assess improvements of CBRFC forecasting and End User implementations.
3. Accelerate applications: Ensure that NASA's flight missions plan for and support applications goals in conjunction with their science goals, starting with mission planning and extending through the mission life cycle	Investigation of hydrologic modeling, prediction and water resources management utility of current MODIS products with respect to their variations in uncertainty, view geometry, frequency of acquisition.

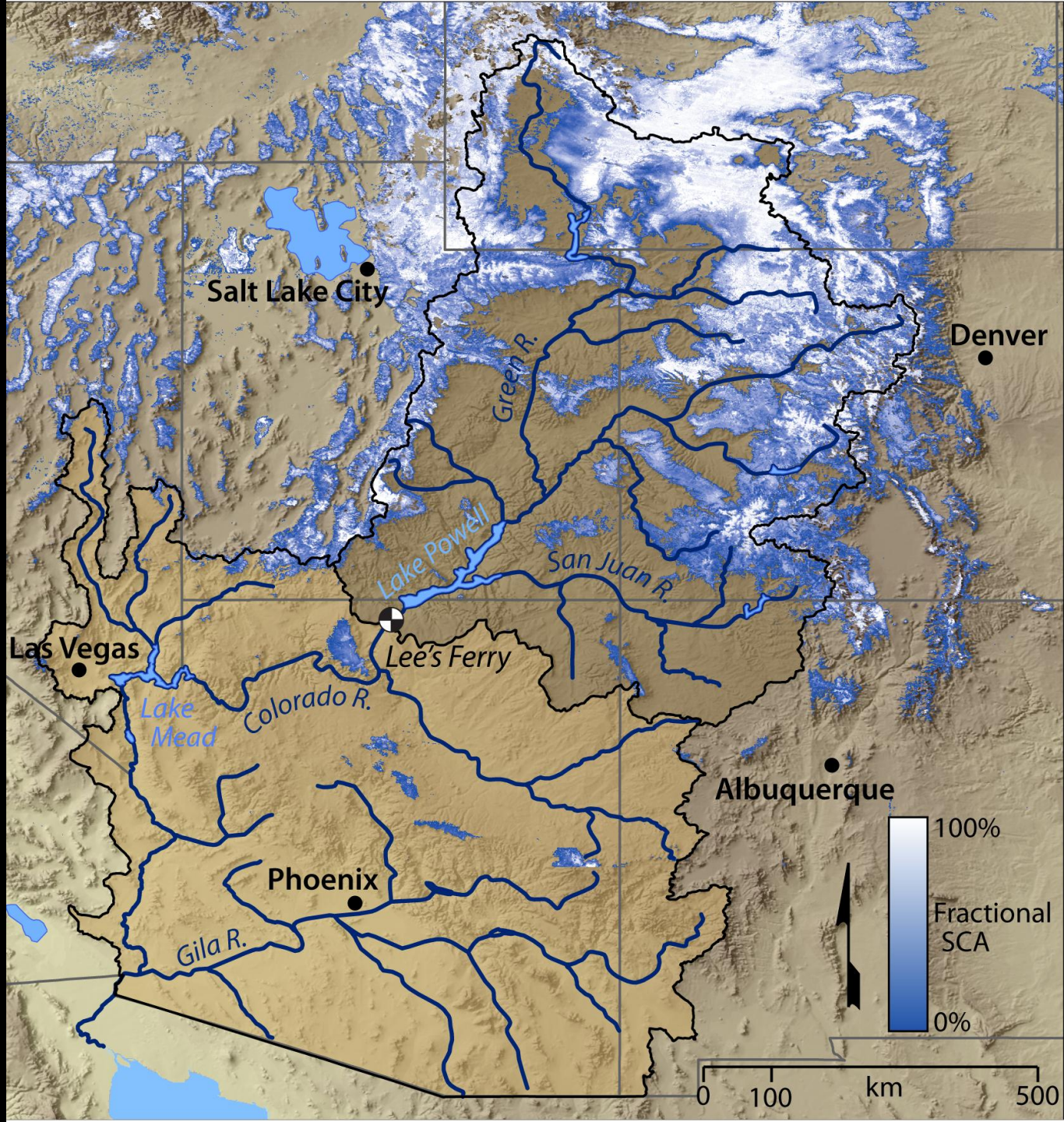
MODSCAG

Fractional Snow Covered Area and Snow Detection (not just in the mountains)

JPL Snow Server

Operational through:
NOHRSC
GOES-R ABI

Painter et al 2009
Dozier et al 2008
Rittger et al 2012

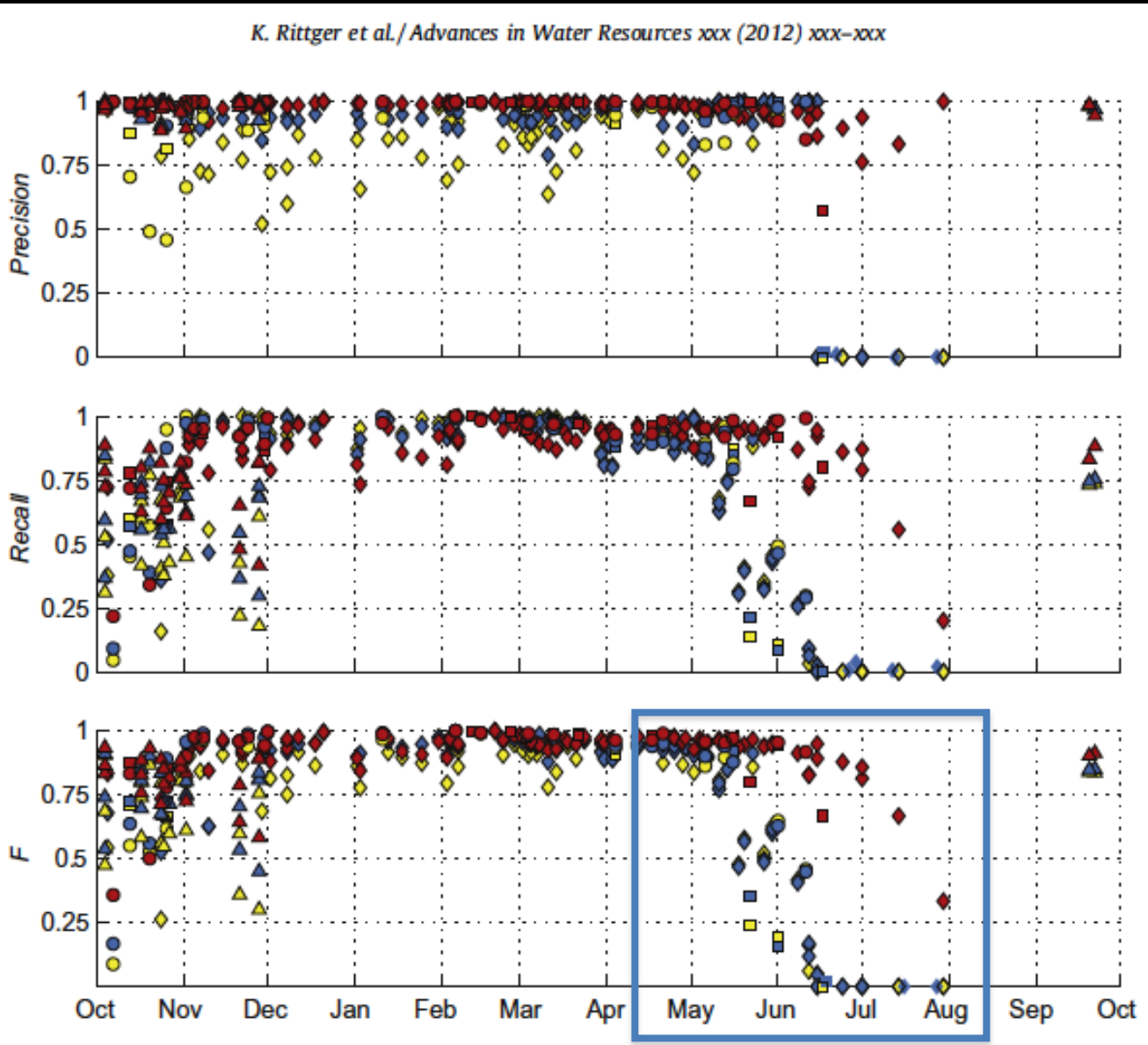


Precision is the probability that a pixel identified with snow/ice indeed has snow/ice.

Recall is the probability of detection of a snow/ice-covered pixel.

F = Precision x Recall

DETECTION



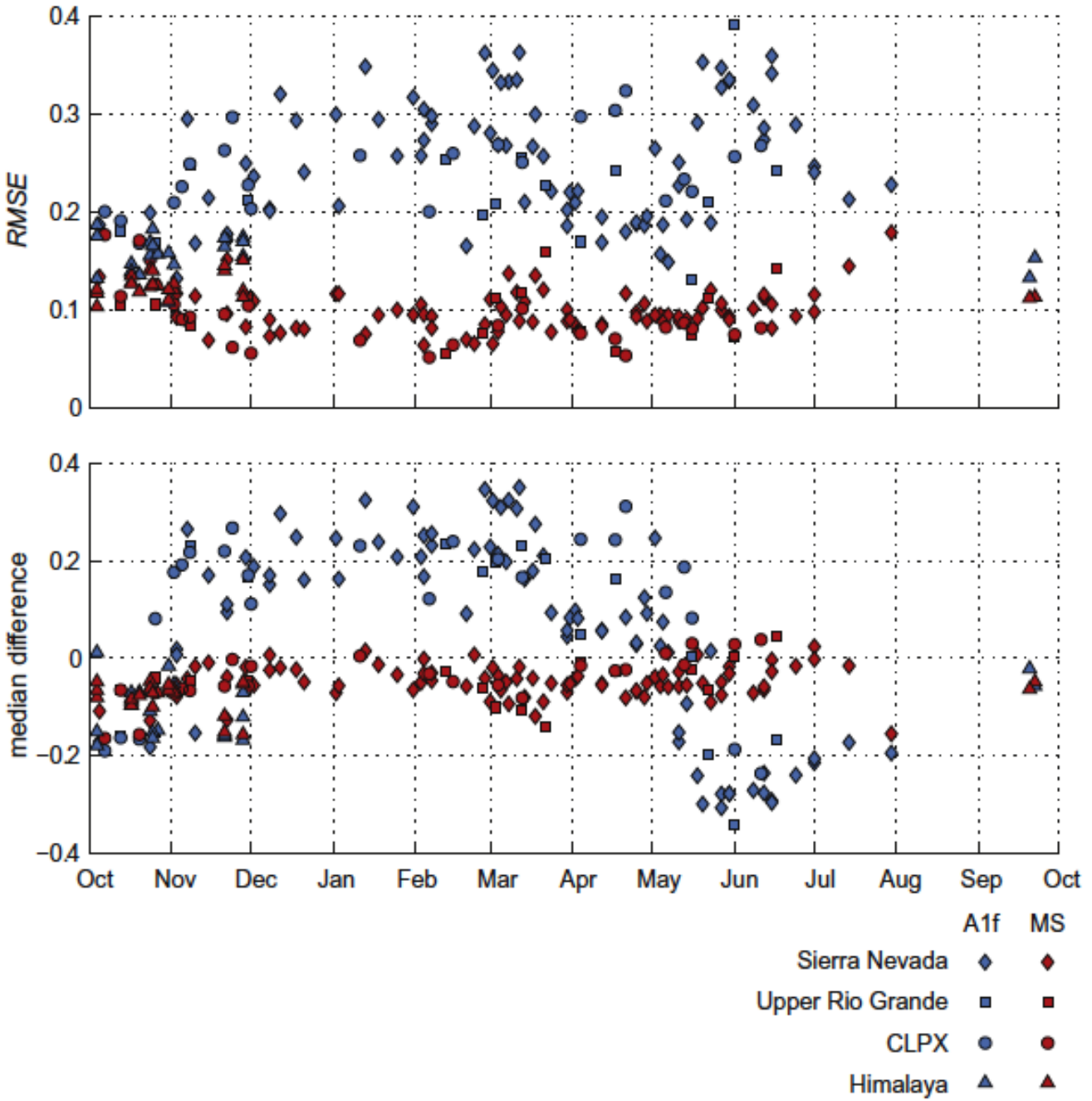
Comparison of MODSCAG (MS) with MOD10A1 binary (A1b) and fractional (A1f)

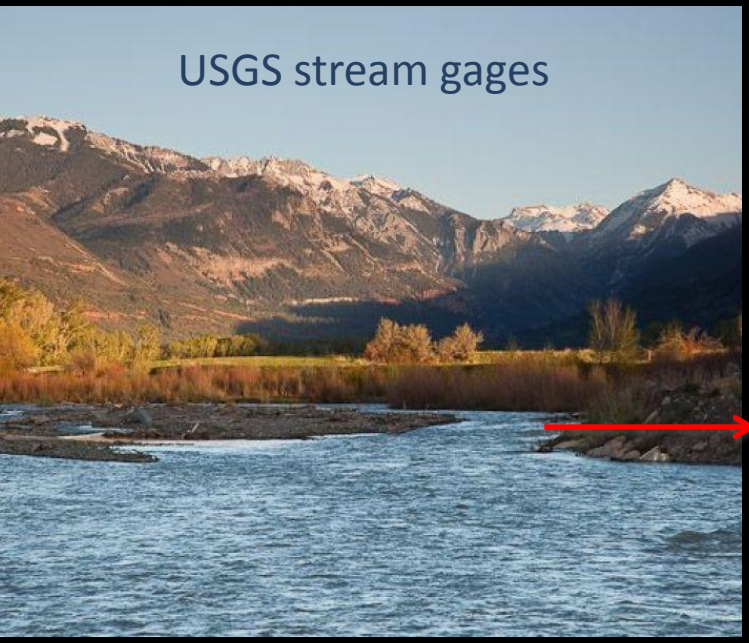
Rittger et al 2012

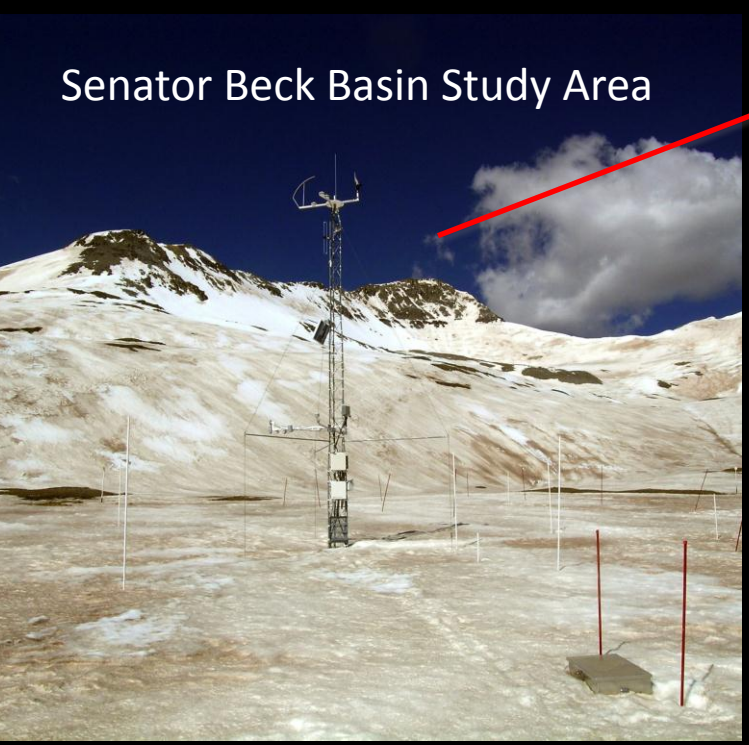
Root mean squared error against Landsat Thematic Mapper retrievals.

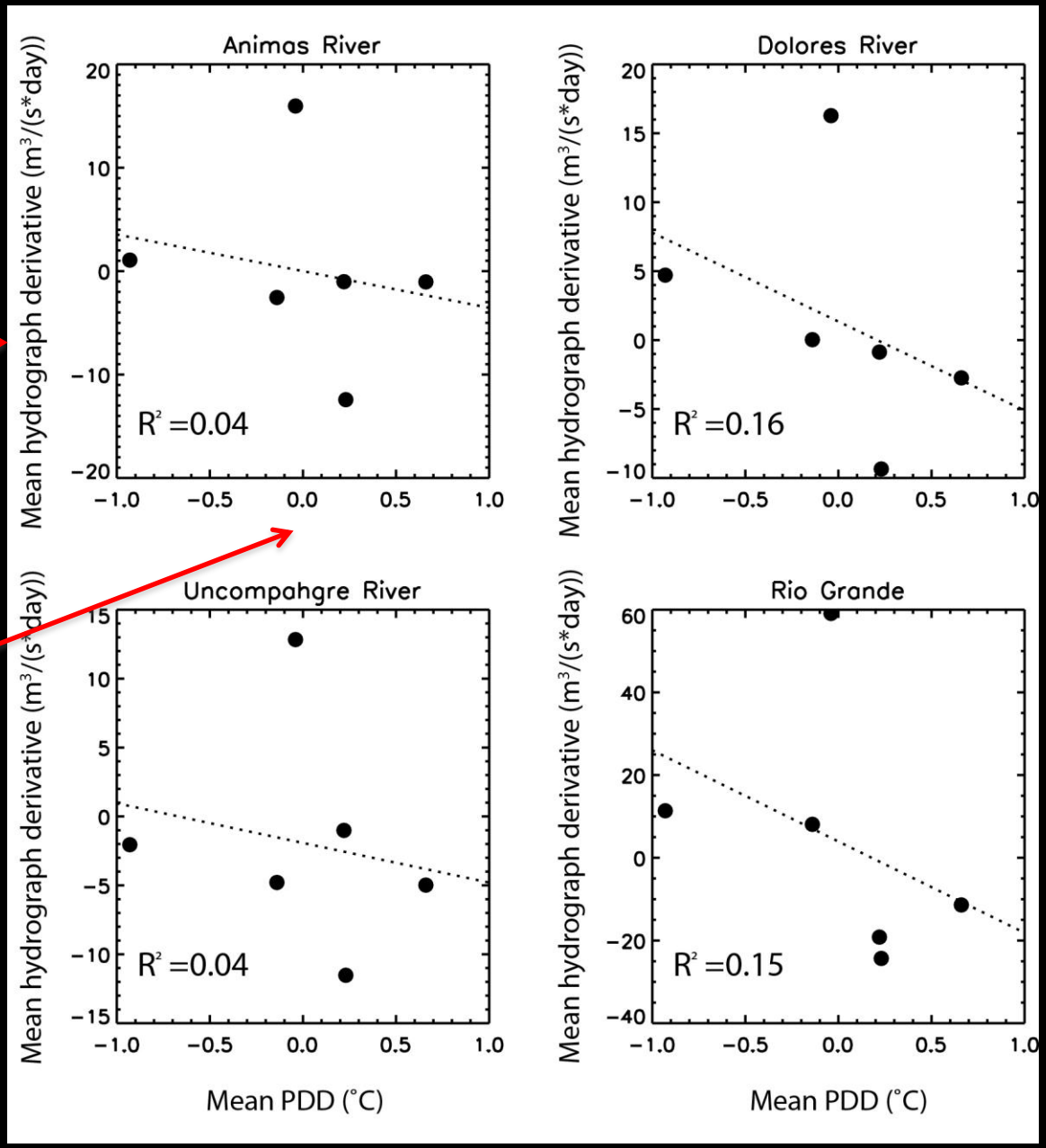
Median error against Landsat Thematic Mapper retrievals.

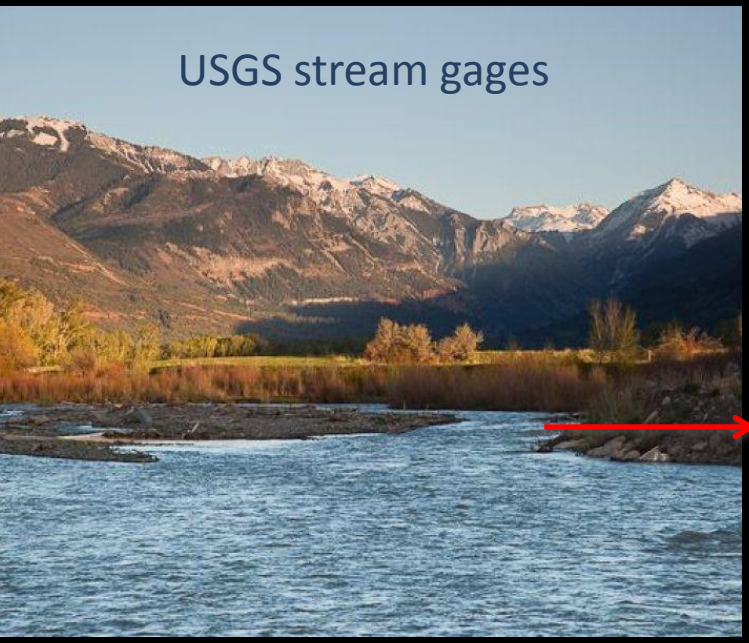
QUANTIFICATION

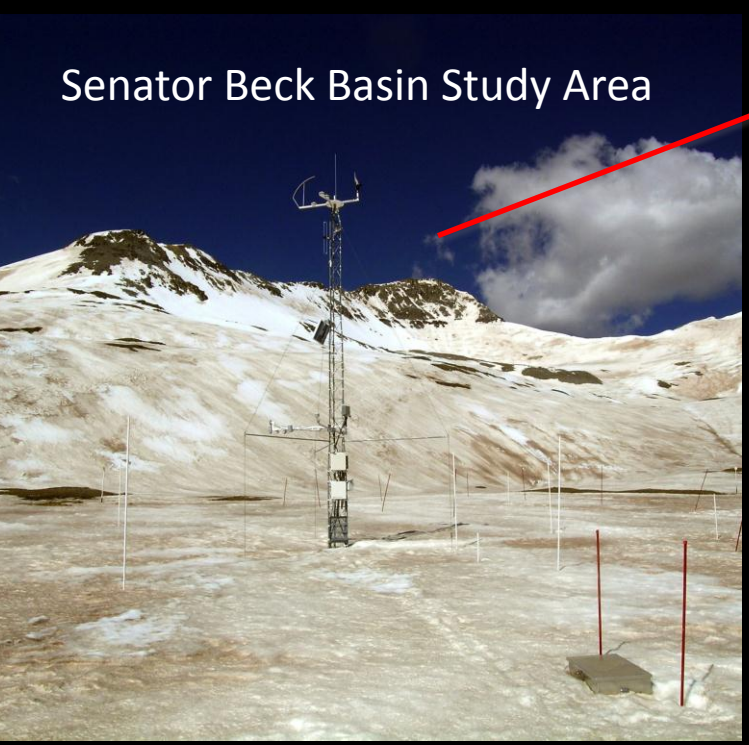


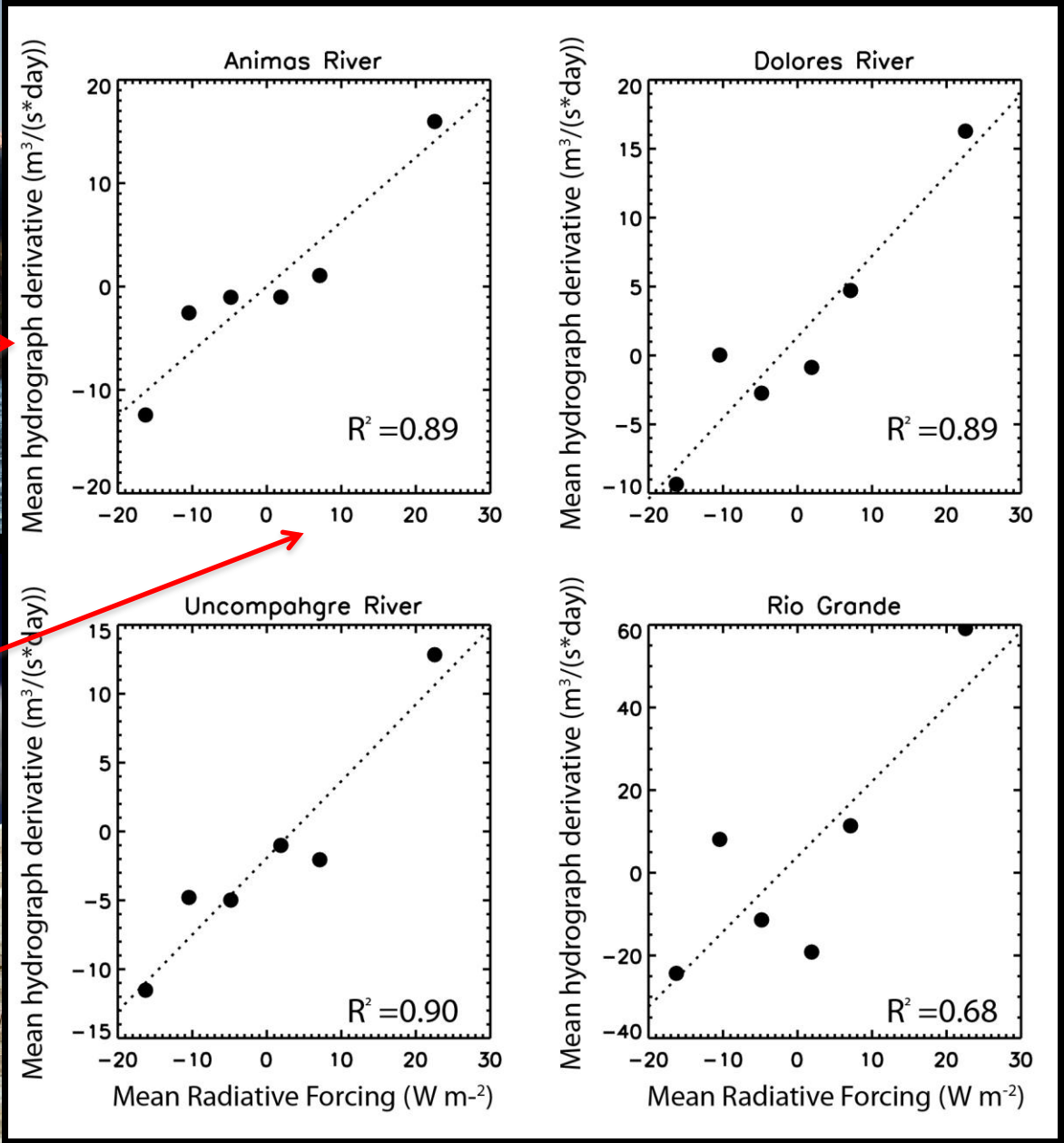

USGS stream gages


Senator Beck Basin Study Area

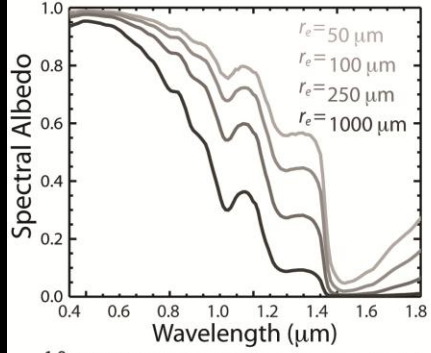

Animas River
Dolores River
Uncompahgre River
Rio Grande
Mean hydrograph derivative (m³/(s*day))
Mean PDD (°C)
R² =0.04
R² =0.16
R² =0.04
R² =0.15

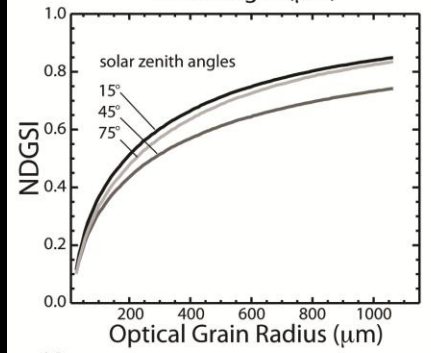

USGS stream gages

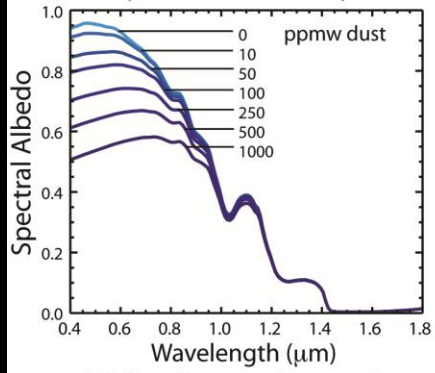

Senator Beck Basin Study Area

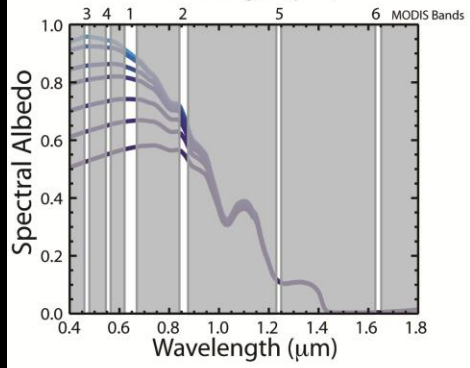

Animas River
Dolores River
Uncompahgre River
Rio Grande
Mean hydrograph derivative (m³/(s*day))
Mean Radiative Forcing (W m-2)
R² =0.89
R² =0.89
R² =0.90
R² =0.68

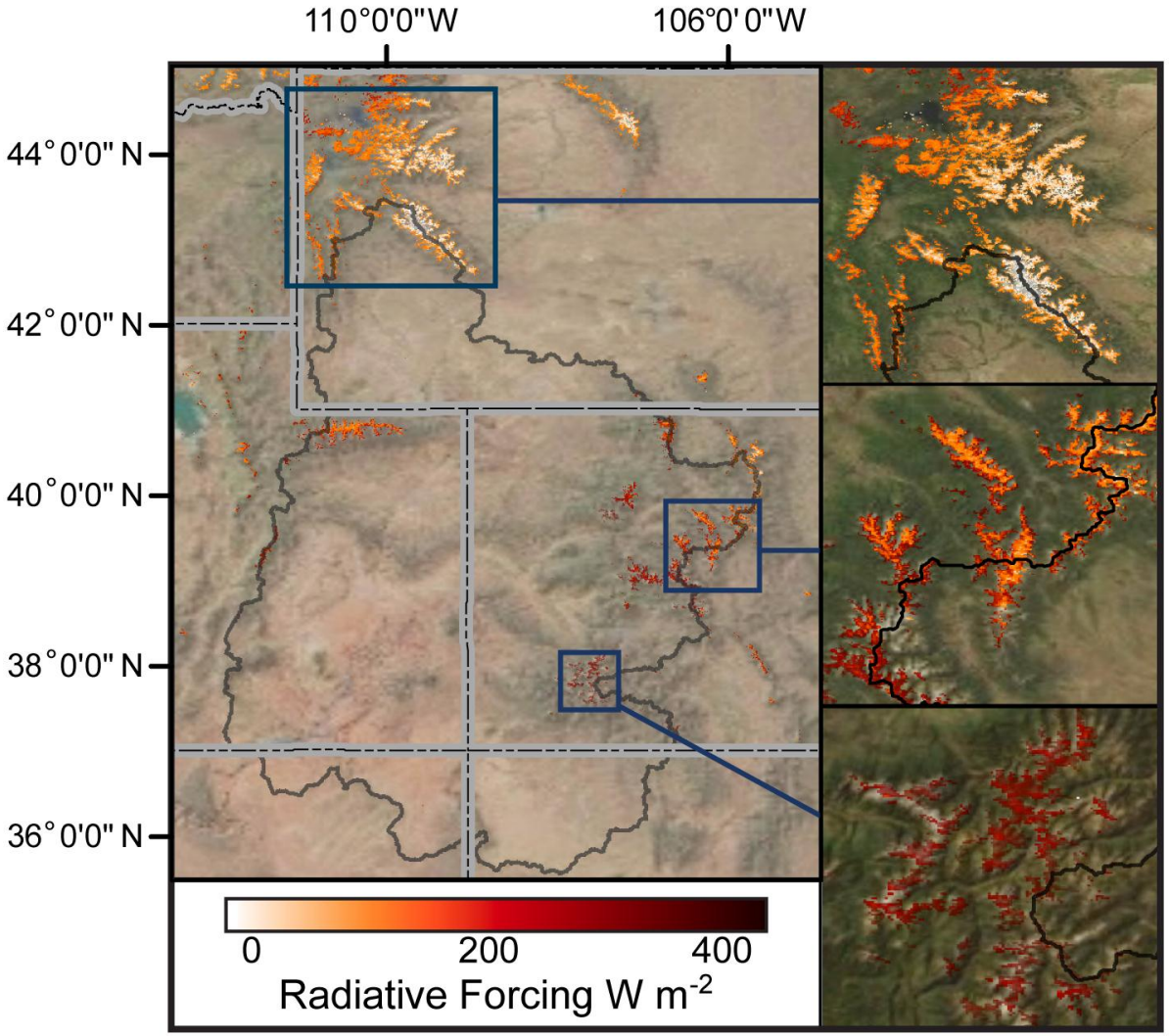
MODDRFS – dust radiative forcing in snow



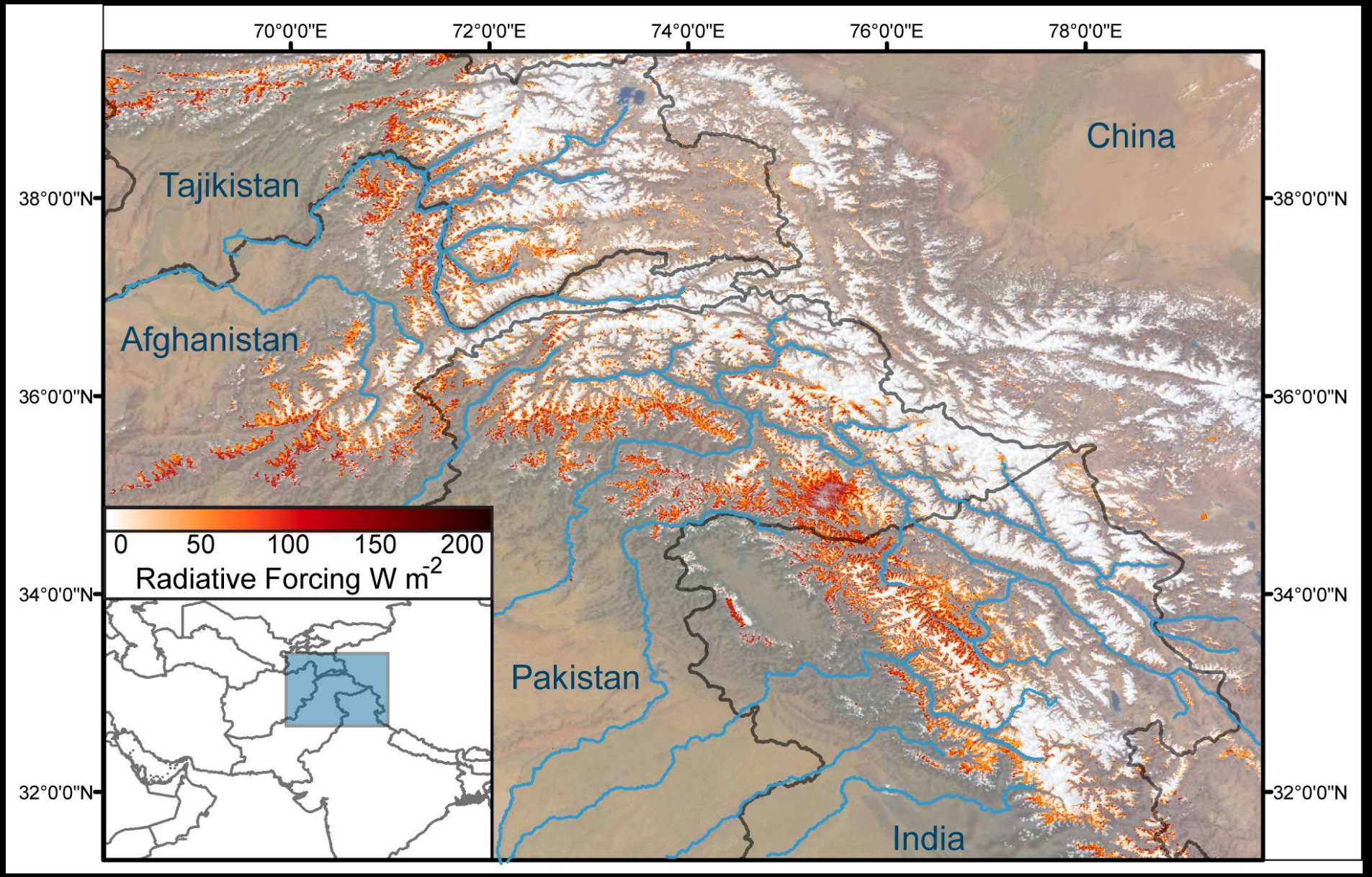




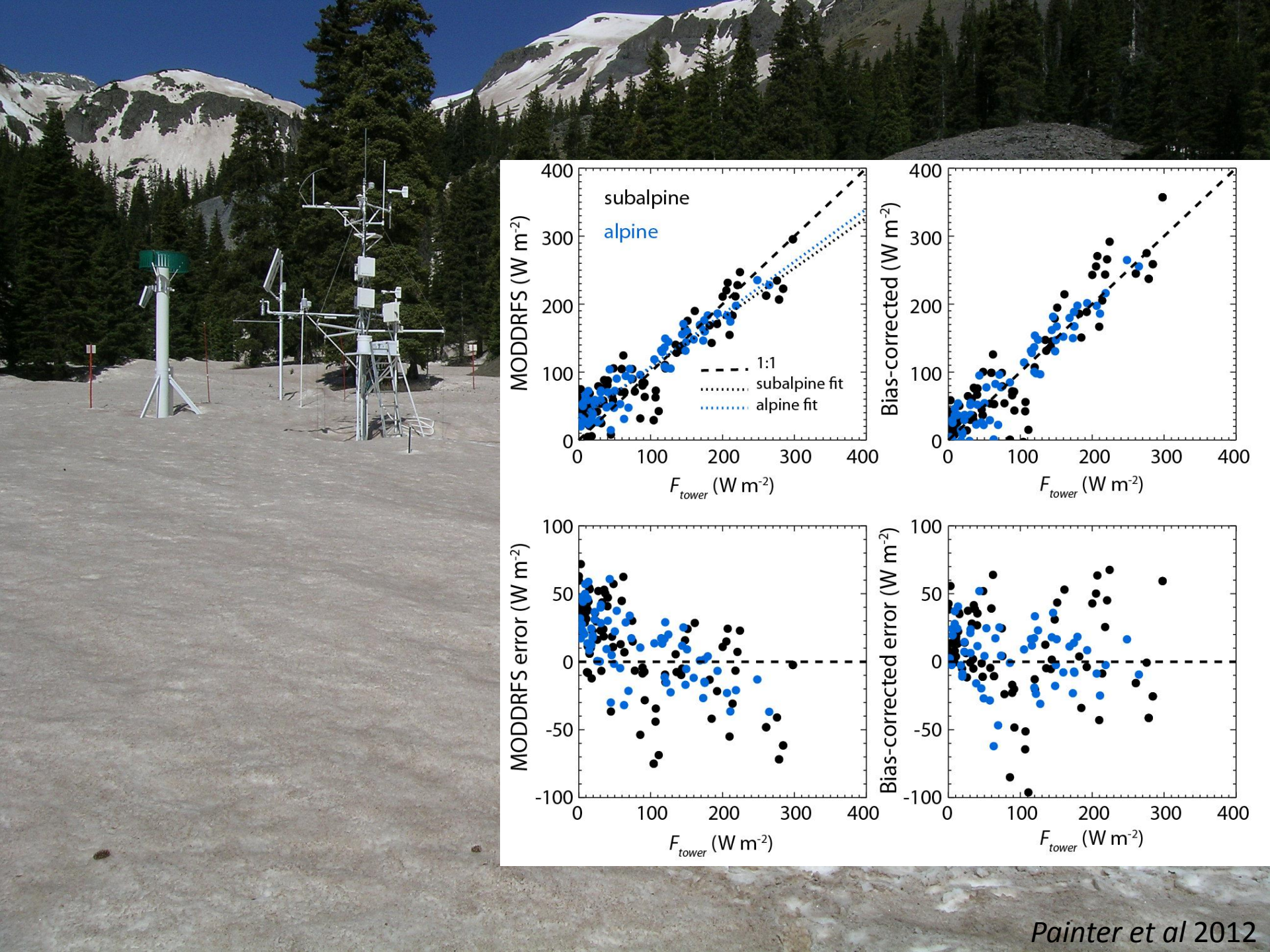




Painter et al 2012



Hindu Kush-Himalaya



Painter et al 2012

Integration of MODSCAG and MODDRFS in CBRFC operations

(1) Ingest and display of MODSCAG for qualitative use by RFC forecasters in WY2013

- Since May 2012, CBRFC is ingesting and displaying daily MODSCAG grids
- Time series of scalar estimates of snow cover – available Sept 2012 in-house at CBRFC

(2) Parallel experiments/testing prior to operational use of MODSCAG at CBRFC

- Retrospective case studies of rapid melt event in June 2010 in snow-dominated headwater basins
- Provide an initial look at how the quantitative use of MODSCAG in CBRFC's modeling system affects streamflow forecasts (complete by end of 2012)
- Real time parallel model runs during spring 2013 in selected snow-dominated headwater basins
- Monitor how streamflow forecasts from a parallel execution of the model that uses MODSCAG compares to the official operational runs (no MODSCAG use), in real time

Integration of MODSCAG and MODDRFS in CBRFC operations

(3) Integration of MODSCAG into CBRFC operations

- Depending on the results of MODSCAG experiments at the RFC, decide whether further quantitative experiments/testing is necessary, or decide how to implement use of MODSCAG in operations for winter 2013-2014.

MODDRFS at CBRFC

- *Snow-17 does not handle albedo nor net shortwave – therefore, the use of MODDRFS will begin as subjective nudging*
- Make MODDRFS grids available for qualitative use by RFC forecasters via display of grids in CHPS

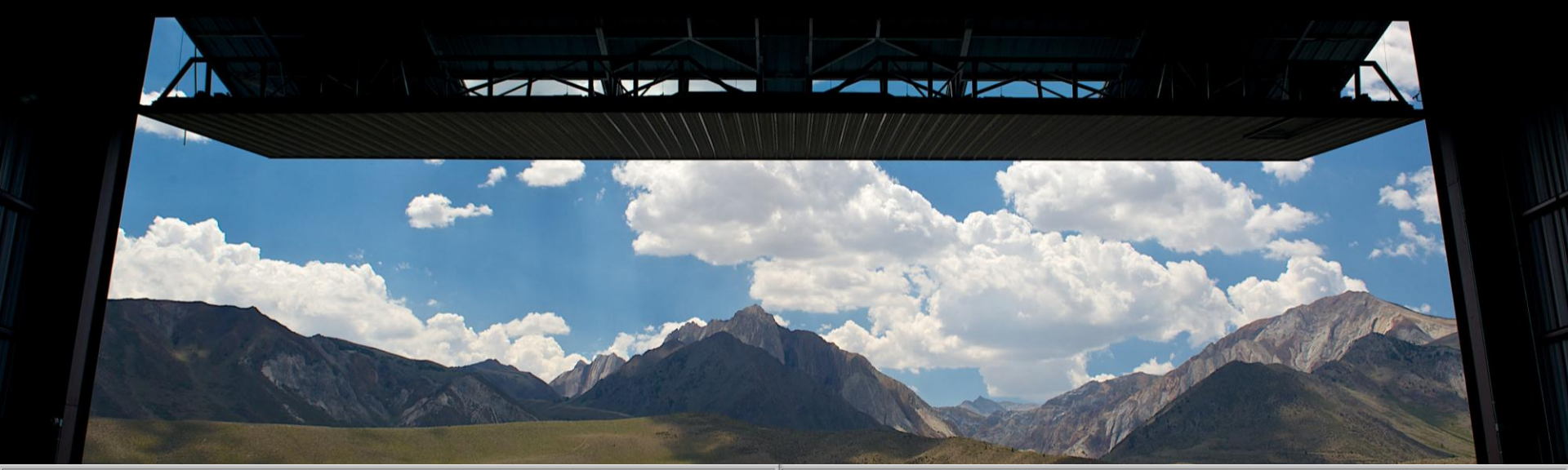
Anticipated Improvements

Cases under which MODSCAG will be useful with respect to updating model snow conditions and to snowmelt-driven streamflow forecasting

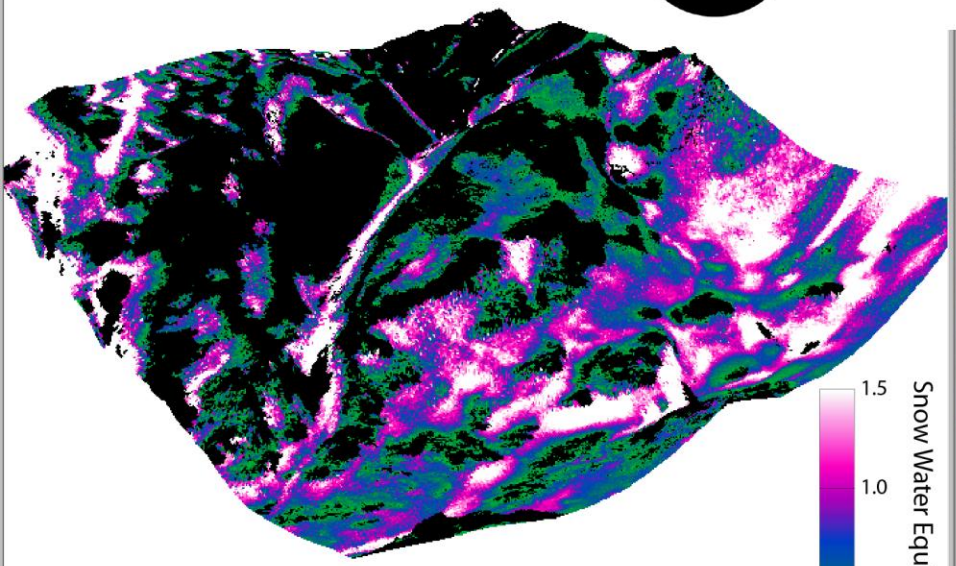
- Observed snow cover differs greatly from the model snow cover and a large correction is needed.
- Rapid melt (in particular how rapidly snowpack is disappearing)
- When snow pillows melt out
- When snowpack persists in places where it should have melted out (south faces, lower elevations – example: June 2010)

Strategy for Quantifying Impacts

- End Users will access same graphical representations of model and remotely sensed datasets as the forecasters and research team.
- Qualitative and quantitative metrics related to forecast verification in the basins of interest to our end user collaborators (the Upper Colorado for Denver Water, the Upper Colorado and Gunnison Basins for Colorado River District, and the Gunnison Basin for USBR) – in season and a posteriori
- Weekly telecons with End Users determining their use of remote sensing-enhanced and nominal forecasts
- The CBRFC annual year in review + 2-day assessment workshop at CBRFC for all End Users and expanded community



Airborne Snow Observatory



Snow water equivalent
San Juan Mountains
11 May 2012

AVIRISng color composite
San Juan Mountains
11 May 2012